FREEZE-DRYING COSTS; SOME QUESTIONS AND ANSWERS

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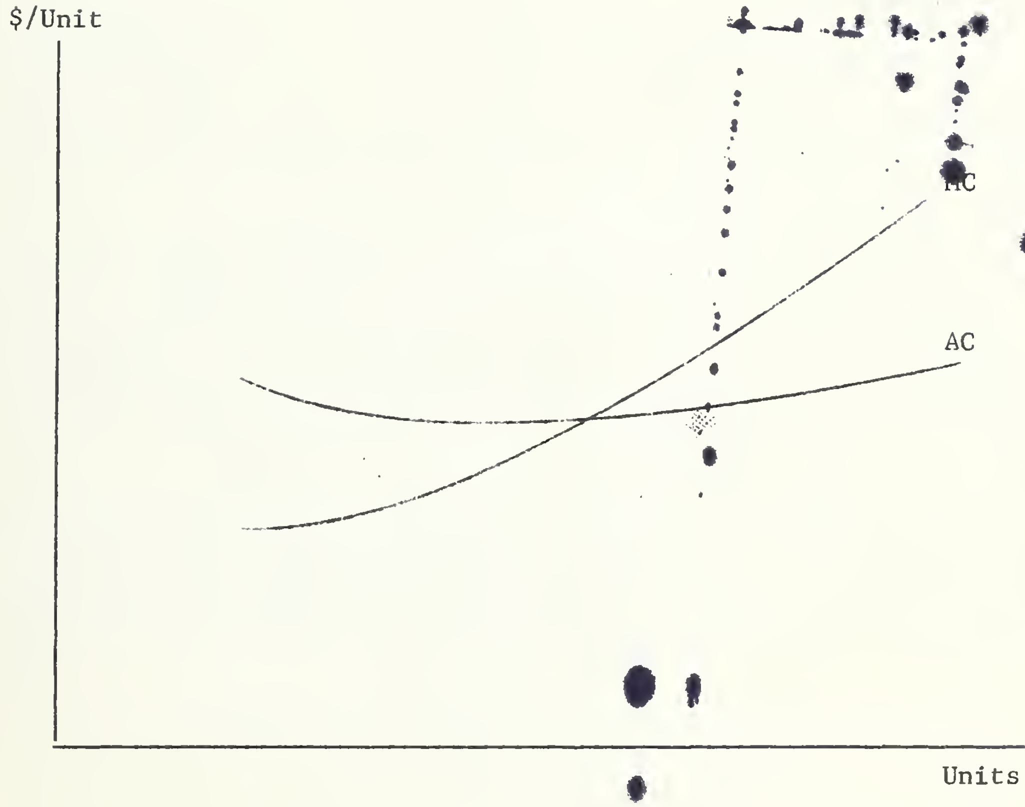

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Having completed a study of the processing costs of freeze-drying, I have acquired a great respect for the work of cost engineers. Although I am going to report on one phase of our cost work in the Department of Agriculture, at this meeting I would rather listen than talk. My reluctance to expose my lack of knowledge of cost engineering reminds me of the saying of James Agate, "The English instinctively admire any man who has no talent and is modest about it."

One aspect of food preservation that has caught the imagination of many is freeze-drying. Some people seem almost to worship it. They feel that at the minimum it will upset old notions and practices in food processing. Others accept it has mildly interest, but feel it has no great future as a food processing method. Those completely unimpressed ask, "So, what else is new"? However, almost all inquirers have a common interest in freeze-drying processing costs, for they appear to be one important key to the future of the industry.

Here, we shall try to remove a little of the mystery surrounding freeze-drying costs by using the question and answer method. An old proverb states, "A fool may ask more questions in an hour than a wise man can answer in seven years". Our questions are a 7-year bundle, but we shall try to respond to them in the time allotted--acknowledging that in some instances complete answers are unavailable. Since I have simple answers, I shall ask myself reasonably simple questions.

* What cost elements are involved in freeze-drying?

* How high are food freeze-drying costs?

* How did we get our cost data?

* How reliable are the cost estimates?

* May we freeze food in the freeze-drying vacuum chamber and in this way lower costs?

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* Are refrigerated shelves within a cabinet necessary, and do they raise or lower costs?

* Why are freeze-drying packaging costs high?

* Do high freeze-drying costs limit the market for these foods? What other factors limit their market?

* What are the freeze-dried food markets of the future? What foods seem important to the future? How big will the industry get?

The main costs involved in freeze-dehydration are: Amortization of drying equipment, labor, utilities, and amortization of buildings and other equipment. Lesser cost items include salaries of management, repairs, and research and development costs. Research and development costs are difficult to determine and allocate to the freeze-drying process. The costs we will be discussing are drying costs only. They do not include food preparation, research and development, freezing, packaging, and storage costs.

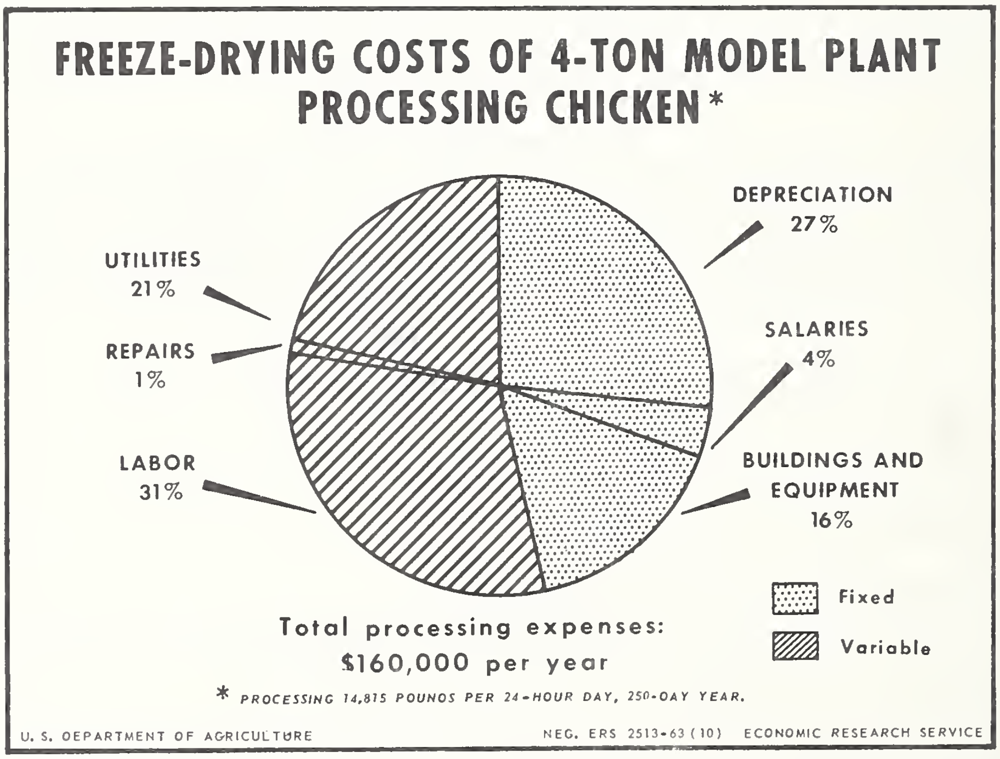

Figure 1

How high (or low) are freeze-drying costs? We start our discussion with some rule-of-thumb generalizations and become more specific as we go along. Some freeze-dried processors have calculated their costs to be in the range of $.45 to $.50 per pound of dry product. This would be equivalent to about $.25 per pound of water removed or $.17 per pound of wet weight product. Dehydration engineers think of costs in terms "per pound of water removed" and we use that terminology here. Other cost estimates range downward to as low as $.02 per per pound. However, I look upon cost estimates of anything less than $.07 per pound of water removed as being completely out of touch with reality. In the future, though, I foresee that a large volume plant, handling one product, operating 300 days per year, running around the clock on a 24-hour-a-day basis, having reasonable utility costs, might have drying costs as low as $.04 to $.05 per pound of water removed. It would be unusual to find such a plant in operation today.

In our study of freeze-drying costs, we used the economic-engineering model approach. This seemed necessary because the plants then in existence were too small to yield cost estimates useful in an accounting or time and motion study. Also, there was and still is a secrecy surrounding the freeze-drying process, and most plant managers did not welcome strangers in their drying establishments. Nor did we want to publish material that would disseminate their guarded information. Thus, we described and analyzed four imaginary or synthetic freeze-drying plants with water removal capacities of 4, 8, 16, and 32 tons per day, if operated on a 24-hour-a-day basis. We operated these four plants using four foods: Shrimp with 70 percent moisture, chicken at 56 percent, mushrooms with 90 percent water, and beef at 60 percent moisture. We selected these four foods to show how different moisture content input products affect costs. For each of the four capacity plants, drying each of the four foods, we estimated building size, equipment needs, labor, utilities, and management requirements. We combined these inputs to make our "paper models" approximate actual operating conditions. By adding prices of the various inputs we were able to calculate average cost curves and other pertinent cost functions.

Using models allow control of the variables affecting efficiency. Construction of a model of this type not only provides a basis for determining cause and effect relations, it also yields insights into underlying physical input and output relations.

Construction of our economic-engineering models involved:

(1) Developing models through

a. Ascertaining the capacities of the plants. Specifying the products to be dried.

b. Finding the physical inputs of labor, management, equipment, building, and utilities for the several stages of production. Determining limiting factors of models.

c. Defining investment needed for equipment and plant. Determining rates of depreciation, interest, maintenance, taxes, and insurance for investment items. Locating the plants geographically.

d. Determining operating conditions within a plant. These concerned product, drying cycle lengths, labor shifts, and lengths of season for each model.

(2) Estimate short-run cost functions by:

a. Obtaining prices of the various input factors. Setting wage rates, utility rates, and other inputs.

b. Determining fixed costs per year for the various products and cycle lengths.

c. Determining variable costs for the several products, cycles, length of season, and labor shifts.

d. Determining total costs per year. Calculate average cost curves when plants are run various ways.

(3) Determine long-run average cost function, or the "economies of size" curve from the series of short-run cost curves constructed for each model.

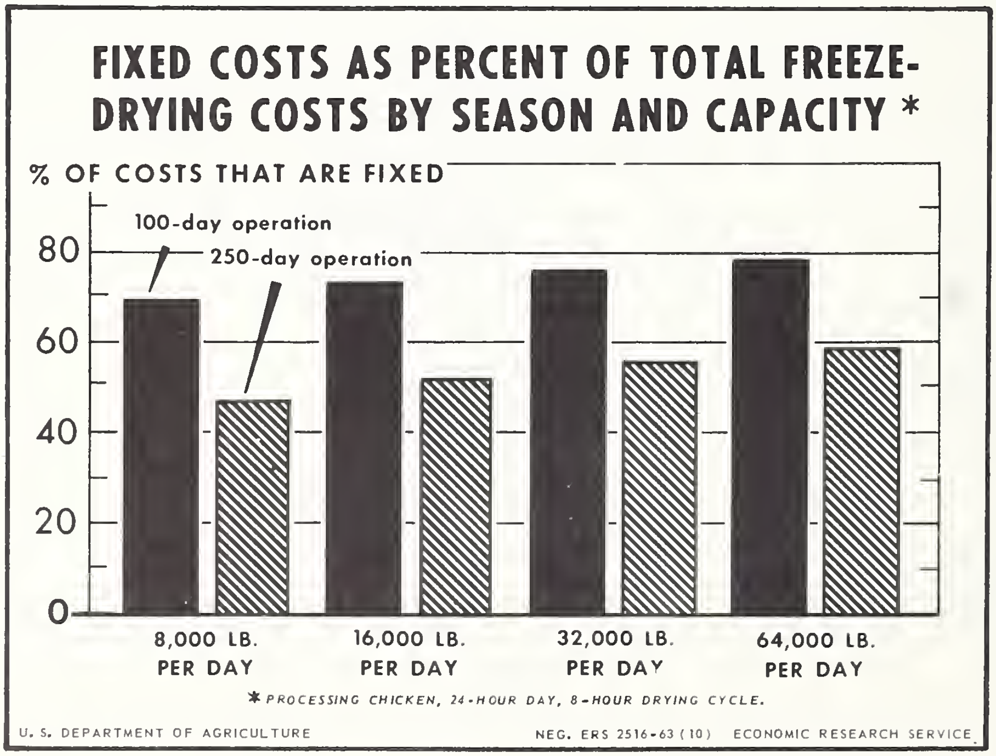

Figure 2

Each model plant, unless otherwise stipulated, was to operate 250 days per year. However, to analyze season length we used a working year varying from 100 to 350 days. We used 8-, 10-, and 12-hour drying cycles in our model plants. Some freeze-drying processors now use cycles of less than 8-hours, although fruits and berries require a much longer drying cycle, sometimes as long as 30 hours. The general trend in the industry has been toward shortened cycles to reduce costs.

Our estimates show what freeze-drying costs would or could be if the conditions specified were in effect. Our synthetically derived costs now appear somewhat lower than costs of actual plants presently in operation. Reason: Few plants are yet able to operate 24 hours per day, 250 days per year, on an 8 hour drying cycle, with one product. It is difficult to keep a plant operating full time, and the problem is one of marketing, rather than production. It's hard to sell everything you can produce.

How reliable are our cost projections? Our costs, computed in 1962, were intended as anticipations of future costs. Now, in 1966 their future is here. Several plants now are as large as our largest model plant that had a 32 tons per day water evacuation capacity. With soluble freeze-dried coffee now entering the nationwide market, a one product plant is a reality.

Our costs as estimated several years ago now seem too low. A higher depreciation figure, perhaps 18 or 20 percent, rather than the 14 percent one that we used, in hindsight seems better. Also, the prices of freeze-drying equipment have not declined at as fast a rate as I had anticipated. Despite these shortcomings, we have been satisfied with our 1962 cost estimates. Now let's discuss some current cost aspects.

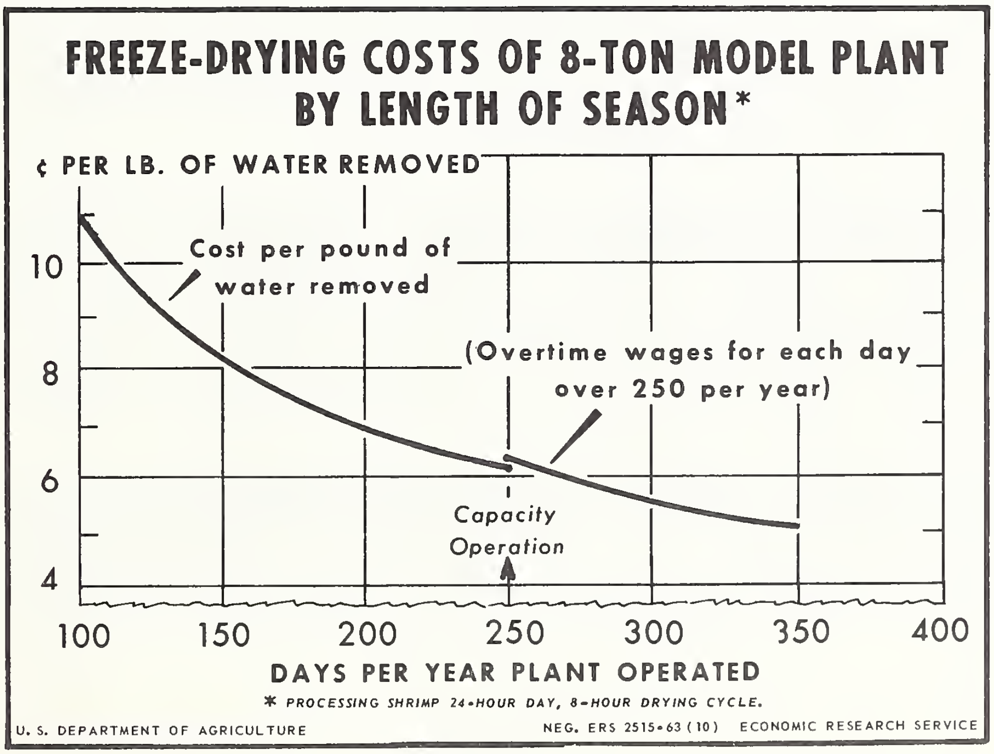

Figure 3

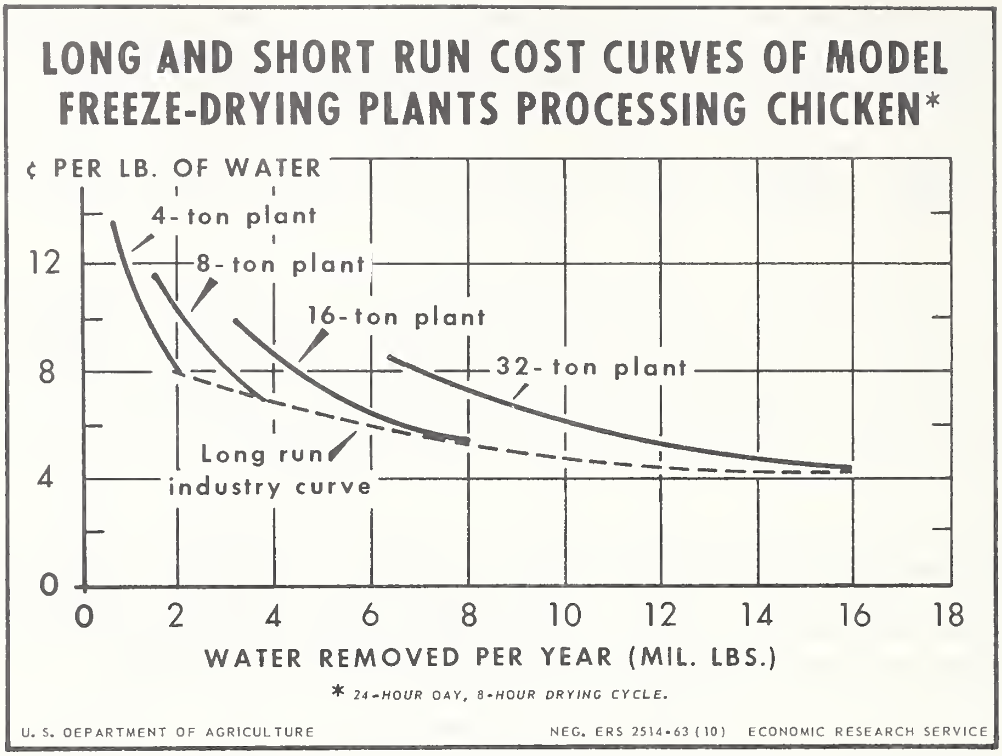

Figure 4

Cooling and freezing foods in the vacuum chamber is mentioned as a way to save handling. Does is lower total processing costs if we freeze food in the vacuum-drying chamber before the freeze-drying takes place? This technique is possible and may be done either of two ways: (1) Using refrigerated shelves, in a cabinet or (2) vacuum-freezing in the chamber. Let's discuss vacuum-freezing in a freeze-drying cabinet first.

Several plants now vacuum-freeze food in their freeze-drying cabinets. Mushrooms are adaptable to this freezing method. A disadvantage of vacuum-freezing is that a loss of moisture (sometimes as much as 20 percent) takes place during vacuum-freezing. Shriveling occurs. A second limitation of vacuum-freezing is that it is an expensive heat transfer method. Thirdly, it ties up expensive drying equipment during the freezing. An obvious advantage is that a handling is saved. The technic may be useful for food items where moisture evacuation during freezing is not a serious problem.

Refrigerated shelves installed in a vacuum freeze-drying cabinet are a definite advantage in a laboratory or a pilot plant. Their main use is not to freeze the food within the cabinet, but rather to keep low eutectic temperature foods frozen during that period while the cabinet is being loaded and before the pressure can be lowered. Foods with high sugar content are an example. They are

hard to freeze-dry since they may melt before they can be kept frozen with the low pressure within the chamber. I know of no commercial freeze-drying cabinets with refrigerated shelves, but I foresee their usefulness in drying certain foods such as orange juice concentrate. Now let's discuss some factors that may lower freeze-drying costs.

Freeze-drying processing costs will continue to decline within the next five years. The following processes and innovations may have a salutary effect on costs.

(1) Larger scale freeze-drying plants of the future will have lower costs regardless of whether they use a batch or continuous process. Plants are now larger than they were, and will continue to grow in size as the market expands.

(2) Operate a plant more hours per day and more days per year. Investment in equipment is a major cost item, and longer hours yield more output units. Total fixed cost allocated to more units of output, reduces costs per unit.

(3) Combine freeze-drying with hot air or other methods of drying. A prominet West Coast vegetable drier is now using a combination drying method for peas, corn, red and green bell peppers, pimentos, and celery. There are many ways in which freeze-drying could be combined with other food drying and with other food processing methods.

(4) Continuous freeze-drying, although not yet used in the United States, is now practicable. I think all the American freeze-drying equipment companies now have blueprints for their own version of a continuous drier. Researchers of the engineering group at our Department's Western Utilization Laboratory in Albany, Calif., have several designs that appear feasible. Companies in the Netherlands, Germany, and Switzerland have designs that appear workable. Leybold of Germany has a semicontinuous plant now in operation in Germany and others under consideration. A continuous drying system attains its greatest efficiency when used with liquids or miscible solids. It is not too hard to envision a continuous plant of this type, although with the currently sized plants, I don't see great cost advantages. Lower costs will be possible in the future as engineers design and install larger, specialized, plants for coffee, dairy products, and fruit crystals.

(5) Slush freezing and centrifuging, another food processing innovation, may have a beneficial effect on drying costs. A processor may use this freezing device to remove some of the moisture preliminary to freeze-drying.

(6) Microwave applications appear nearing the commerical stage. The group of research papers on this subject given at the IFT meeting in Kansas City in 1965 showed that this type energy may be transmitted to the food being dried within a vacuum chamber.1/ Investment cost and utility cost of microwave installations are still high, but reduced cycle times allow savings that may at least partially offset them. Also, freeze-drying equipment investment does not need to be so high, for a given volume flow, because microwave heating shortens drying cycle times.

(7) Irradiation, combined not only with freeze-drying but with other drying methods as well, reduces rehydration times. It also may cut down on drying cycle times. Preliminary research with irradiated foods leads us to believe that it is feasible to combine the irradiation process not only with dehydration, but with many food processing methods.

Packaging costs of freeze-dried foods are generally higher than for other processed foods, since the package is of a more protective type design. Although freeze-drying packaging costs are high at present, they should decline as more efficient packages become available and as larger scale allows use of automatic packaging equipment.

High processing costs limit the market for freeze-dried foods, but factors such as palatability and texture of the foods are important. A limiting factor that confronts all dried foods is the almost overwhelming competition from canned and frozen foods. Freeze-dried foods that have the greatest potential market, other than the ones now on sale are: Eggs, fruit and vegetable powders, flavorings and extracts, fish other than shellfish, prepared potato products, fruit slices, and berries.

Future size of the Industry

Although the future of freeze-drying is still uncertain, I believe it will continue to grow each year for the next 5 years. If our 50 million pound estimate for 1965 is correct, and we foresee an increase of 63 percent per year, we could then forecast a 460 million pound volume in 1970, and 750 million pounds in 1971. These projections assume a decreasing cost structure resulting from advances in technology and management. They also assume a continuing improvement in the whole gamut of dried foods.

1/ During the past several years RCA and North Carolina State University have cooperatively conducted an applied research and development program on microwave application to freeze-drying. Derivedssynthetic data and additional studies with potential users of rf (radio-frequency) processing demonstrate economic advantages. Predicted costs of rf-accelerated freeze-drying, both in batch and on a continuous basis, are less than three cents per pound of input product. This cost estimate is significantly lower than present freeze-drying costs. Capital investment for a accelerated freeze-drying installation is approximately 30 percent less than for conventional (radiant) freeze-drying equipment of comparable capacity.

A 750 million pound per year industry will require about 400,000 square feet of drying shelf area (or the equivalent in terms of a continuous operation). Our present industry has drying shelf area of about 70,000 square feet. Thus we will need to add at least 330,000 square feet of shelf area in the next 4 years. In addition, we will probably replace or redesign most of the drying equipment now in operation. If we imagine 360,000 square feet of drying shelf area to be added or renewed, this represents an investment of about $45 million in drying equipment and perhaps an equal amount in buildings, handling and freezing equipment, storage units, and associated investment items. If our assumptions are correct, the industry will be investing about $90 to $100 million in the next 4 years.

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